

## GEOSYNTEC CONSULTANTS

## COMPUTATION COVER SHEET

Client: WM Project: King George XL Project/Proposal #: ME0169 Task #: 05

## TITLE OF COMPUTATIONS SLOPE STABILITY OF BIOREACTOR AREA

COMPUTATIONS BY:

Signature

*Douglas T. Mandeville*

3/21/01

DATE

Printed Name

Douglas T. Mandeville

and Title

Senior Staff Engineer

## ASSUMPTIONS AND PROCEDURES

CHECKED BY:

(Peer Reviewer)

Signature

*William M. Steier*

3/21/01

DATE

Printed Name

William M. Steier

and Title

Assistant Project Engineer

## COMPUTATIONS CHECKED BY:

Signature

*William M. Steier*

3/21/01

DATE

Printed Name

William M. Steier

and Title

Assistant Project Engineer

## COMPUTATIONS

BACKCHECKED BY:

(Originator)

Signature

*Douglas T. Mandeville*

3/21/01

DATE

Printed Name

Douglas T. Mandeville

and Title

Senior Staff Engineer

## APPROVED BY:

(PM or Designate)

Signature

*Michael F. Houlihan*

3/21/01

DATE

Printed Name

Michael F. Houlihan, P.E.

and Title

Principal

## APPROVAL NOTES:

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## REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL
1	1-6,8	3/10/01	DTM/Hypographical corrections made	WM 3/10/01	MFH 3/10/01





Written by: Doug Mandeville Date: 2/22/01 Reviewed by: Bill Steier LMV Date: 3/21/01  
Client: WM Project: King George XL Proj./Proposal No.: ME0169 Task No.: 05

## SLOPE STABILITY OF BIOREACTOR AREA

### PURPOSE

The purpose of this calculation is to evaluate the slope stability of the bioreactor configuration of the King George landfill. This bioreactor program is being operated under the EPA's XL program. For the landfill to operate as a bioreactor, a significant amount of water needs to be added to the waste mass. This water will be added through the use of gravity fed trenches. The addition of water to the waste mass may increase the weight of the mass as well as the pore pressures in the waste mass. This calculation examines the stability of the existing slope with the addition of the water.

The slope stability analysis is performed to verify that the idealized configuration has an adequate factor of safety against failure under static and pseudo-static loading conditions. According to technical manual published by the USEPA entitled "Solid Waste Disposal Facility Criteria" [USEPA, 1993], the minimum recommended factor of safety against slope stability failure for permanent conditions is 1.5. The current standard of practice when examining pseudo-static conditions is to evaluate the displacement along the slip surface; a displacement of less than 1 foot is considered to be satisfactory [USEPA, 1995 and Seed and Bonaparte, 1992].

### SELECTION OF CRITICAL CROSS SECTION

Figure 1 shows the area in which liquid will be added to the landfill. In examining this Figure, a potential critical section exists at each of the outward facing slopes. The east, south, and west facing slopes have a perimeter berm located at the limit of waste. The north facing slope is not buttressed by a perimeter berm or adjacent waste cells and is therefore selected as the critical cross section. Figure 2 is an idealized representation of the critical cross section.

The liquid application trenches to be used in the bioreactor operations are modelled as a 4 foot thick layer of stone with a phreatic surface located at the top of the liquid application trench. The phreatic surface is assumed to have sideslopes of 1 horizontal to 1 vertical; the waste located under and adjacent to the liquid application trench is influenced by this phreatic surface. The liquid application trench will be located at least 50 feet from any outward facing slopes and will be located at least 2 feet under the surface of the landfill.



Written by: Doug Mandeville Date: 2/22/01 Reviewed by: Bill Steier *[initials]* Date: 3/21/01  
Client: WM Project: King George XL Proj./Proposal No.: ME0169 Task No.: 05

## METHODS OF ANALYSES

The factor of safety of the typical cross section is analyzed using limit equilibrium theory along with the methods of slices. The computer program XSTABL [Sharma, 1996] was used to perform the analysis. The procedure consisted of analyzing numerous potential failure surfaces to find the critical failure surface that results in the minimum factor of safety for the slope.

For this analysis, a circular slip surface is evaluated using Bishop's method. In this analysis, the slip surface is allowed to pass through the underlying soil. A simplified seismic loading analyses (i.e. pseudo-static slope stability analysis) is also performed for the same cross section. The pseudo-static analysis method assumes that the entire soil mass is subjected to the maximum horizontal acceleration (MHA) for the site and assumes that there are no soil amplification effects (the MHA in the bedrock is the same as the MHA in the landfill foundation soil). The MHA is defined as the acceleration with a 90 percent probability of not being exceeded in 250 years. The MHA in bedrock for the King George site is estimated to be 0.15 g, as indicated in Figure 3 [Algermissen et. al., 1990].

## MATERIAL PROPERTIES AND ASSUMPTIONS

The soil material and interface properties used in the slope stability analysis are summarized in the Table 1. The soil properties are identical to those described in the Part B permit application [Rust, 1994]. The waste properties are based on bi-linear failure envelope [Kavazanjian et al, 1995]. In this failure envelope, the waste has a cohesion value of 500 psf up to a normal stress of 770 psf, above a normal stress of 770 psf, the waste has a friction angle of 33°.

Table 1. Material properties used in liner slope stability analyses.

Material	Unit Weight(lb/ft <sup>3</sup> )	Cohesion (psf)	Friction Angle
Cover soil	125	250	25°
Waste <sup>(1)</sup>	75	500	33°
Liner interface <sup>(2)</sup>	100	0	18°
Foundation soil	125	250	25°
Trench Gravel	120	0	30°
Water	62.4	NA	NA

(1) bi-linear failure envelope based on Kavazanjian et al 1995

(2) these properties are used to represent the liner system in this analysis.

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## RESULTS OF ANALYSES

Slope stability analyses were performed for the cross section shown in Figure 2. Table 2 provides a summary of the factors of safety that were obtained in this analysis.

Table 2 - Results of liner stability analyses

	Factor of Safety	Factor of Safety
	Static Analysis (filename)	Pseudo-Static Analysis [displacement] (filename)
Existing conditions	1.53 (kg2ex)	1.15 [0 inches] (kg2exec)
With liquid application trench	1.53 (kg2tr)	1.14 [0 inches] (kg2treq)

Based on the static analysis conducted for the slopes, the factor of safety obtained during the static analyses was greater than the minimum value of 1.5. The addition of the liquid application trench and the phreatic surface associated with the addition of water into the trench does not change the location of the critical surface; the factor of safety remains the same as in the existing conditions analysis.

The displacement along the slip surface of the landfill is estimated for the critical pseudo-static case presented above. A maximum horizontal acceleration of 0.15g resulted in a factor of safety of 1.14. This is greater than a factor of safety of 1, therefore no displacement is expected to occur along the slip surface of the landfill. The recommended maximum displacement along the slip surface is 12 inches, therefore, the landfill design is satisfactory.

Written by: Doug Mandeville Date: 2/22/01Reviewed by: Bill Steier *hmr*Date: 3/21/01Client: WMProject: King George XLProj./Proposal No.: ME0169Task No.: 05

## REFERENCES

Algermissen, S., Perkins, D., Thenhaus, P., Hanson, S., and Bender, B., "Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico", U.S. Geological Survey, Miscellaneous Field Studies Map MF-2120, 1990.

Kavazanjian Jr., E., Matasovic, N., Bonaparte, R., and Schmertmann, G., "Evaluation of MSW Properties for Seismic Analysis", *Proceedings, Geoenvironment 2000, Vol II*, New Orleans, LA, Feb 1995, pp. 1126-1141.

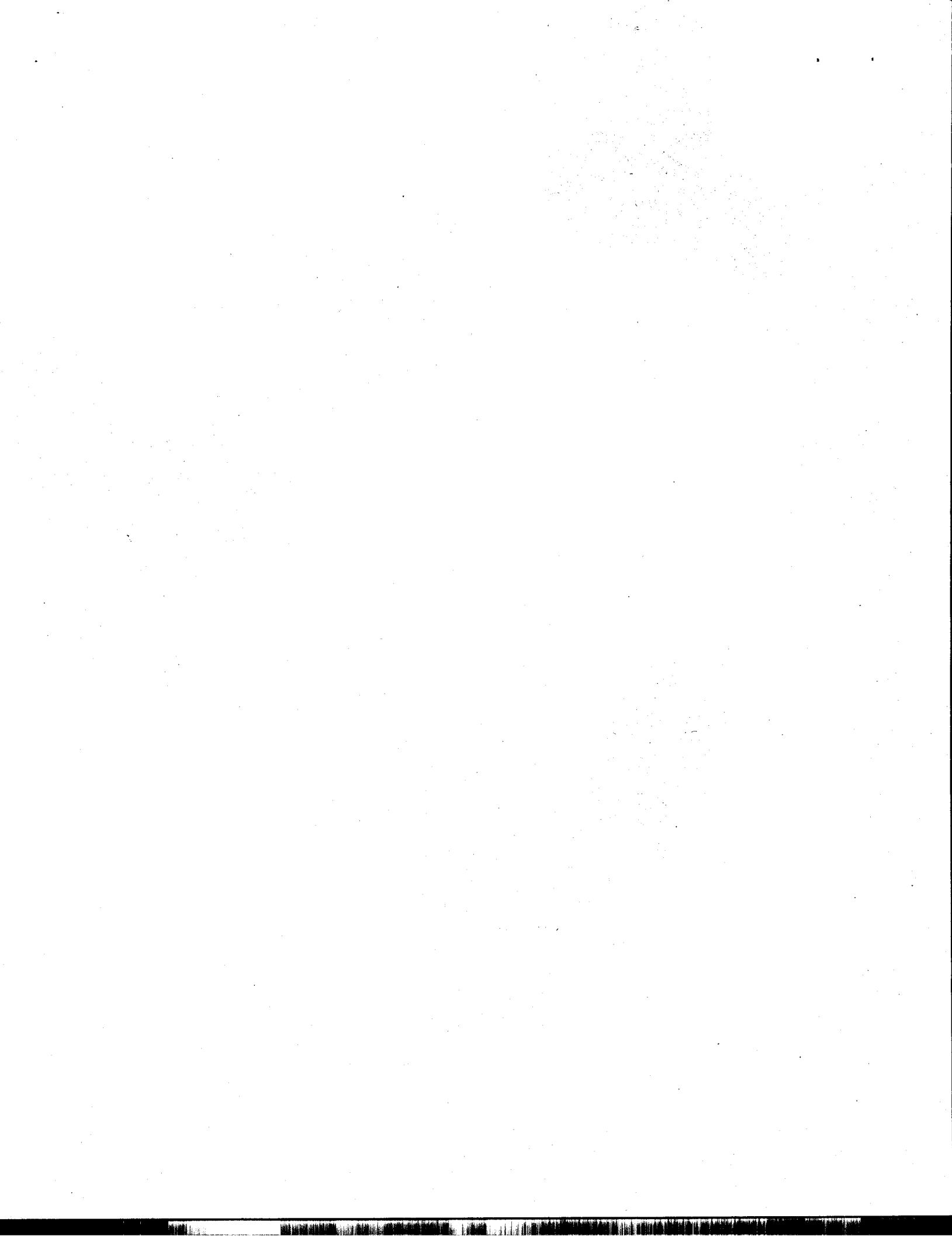
Rust, Part B Permit Application for King George County Landfill and Recycling Center, Bensalem, Pennsylvania, August 1994.

Seed, R.B., and Bonaparte, R., "Seismic Analysis and Design of Lined Waste Fills: Current Practice," Proc. Stability and Performance of Slopes and Embankments - II, Vol. 2, ASCE Geotechnical Special Publication No. 31, Berkeley, California, pp. 1521-1545.

Sharma, S. "XSTABL: an integrated Slope Stability Program for Personal Computers", Version 5.201, Interactive Software Designs, Inc., Moscow, ID, 1996.

United States Environmental Protection Agency, "Solid Waste Disposal Facility Criteria", Document No. EPA 530-R-93-017; November 1993.

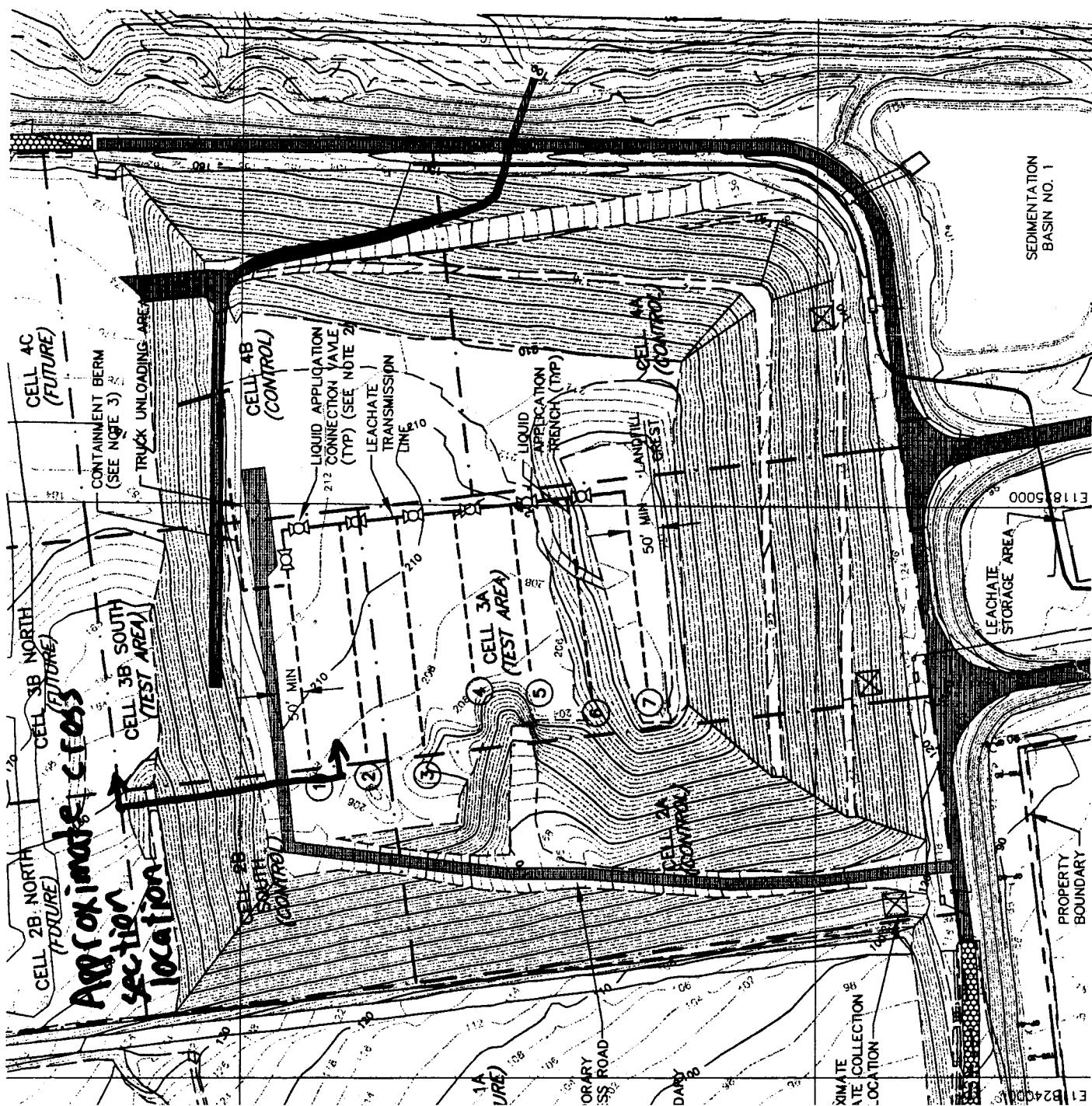
United States Environmental Protection Agency, "RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities," April 1995.



Liquid Application System Layout  
King George County Landfill and Recycling Center

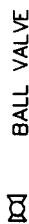
5/20

**App (oxid) section location**



**LEGEND**

— PHASE BOUNDARY  
① LIQUID APPLICATION  
TRENCH IDENTIFICATION



TRENCH NUMBER	LENGTH (FEET)
1	410
2	410
3	410
4	310
5	310
6	360
7	360

**NOTES:**

1. GRADES OBTAINED FROM SURVEY DATED DECEMBER 1999.
2. THE LIQUID APPLICATION VALVE WILL BE A QUICK-CONNECT FITTING INSTALLED ON TOP OF THE LIQUID APPLICATION PIPE FOR TRENCH NO. 1. THE ACTUAL TYPE OF CONNECTOR WILL BE DETERMINED BY KING GEORGE LANDFILL PERSONNEL BASED ON EXPERIENCE WITH SIMILAR SYSTEMS.
3. A ONE-FOOT HIGH SOIL CONTAINMENT BERM WILL BE CONSTRUCTED ON THE NORTH AND EAST SIDES OF THE TRUCK LOADING AREA TO CONTAIN ANY ACCIDENTAL SPILLS OF LEACHATE WHAT OCCUR DURING LEACHATE UNLOADING.

200 100 0 200  
SCALE IN FEET

**GEOSYNTEC CONSULTANTS**

COLUMBIA, MARYLAND

PROJECT NO. MEO169 FILE NO. 0169F206

DOCUMENT NO. 1

GEOSYNTEC CONSULTANTS

Page 6 of 20

Written by: Doug Manderville

Date: YY / MM / DD

Reviewed by: lm

Date: 01 / 3 / 21

Client: WM

Project: King George Project Project/Proposal No.: MEO169

Task No.: 05

Idealized Cross Section

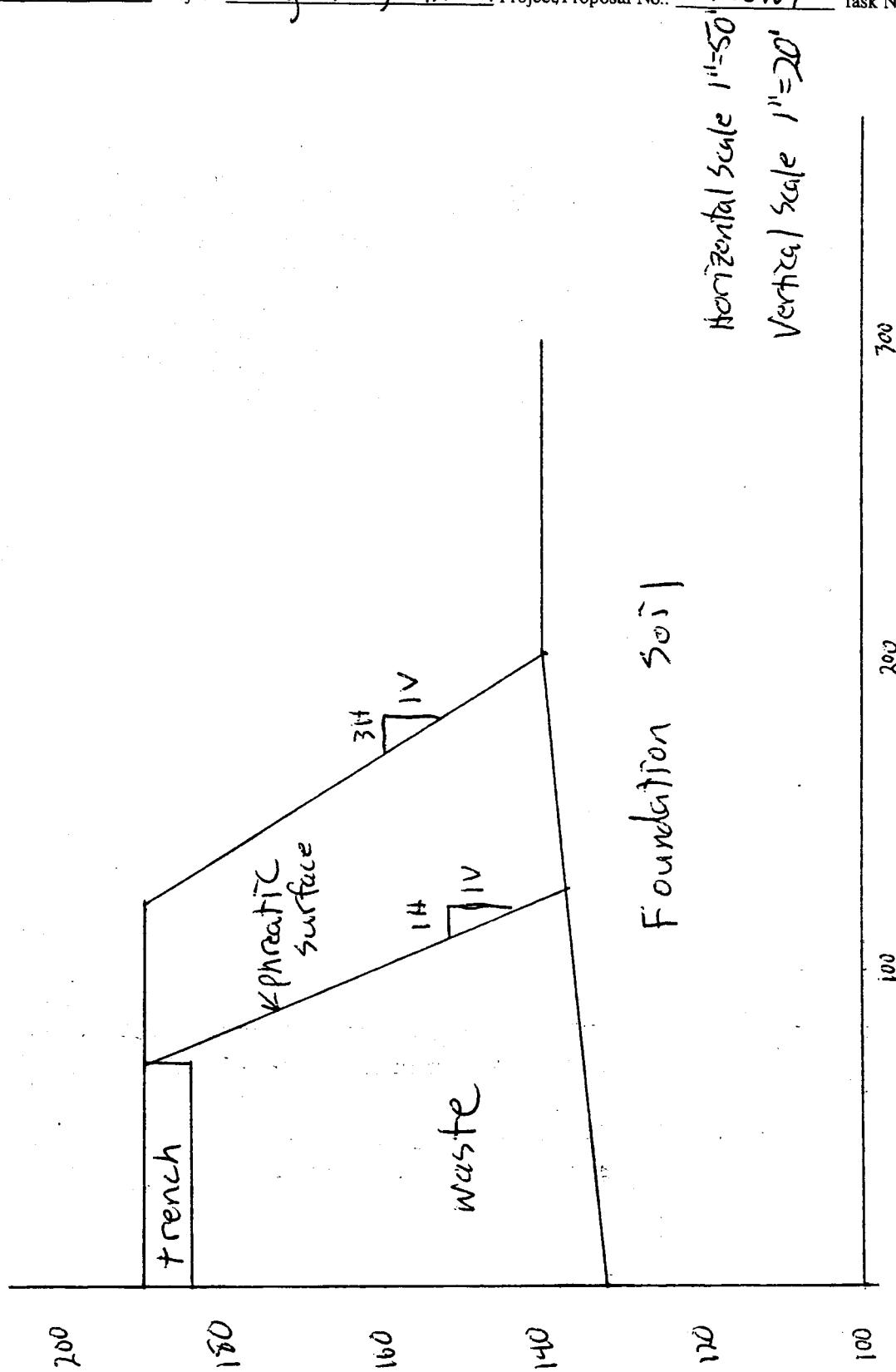
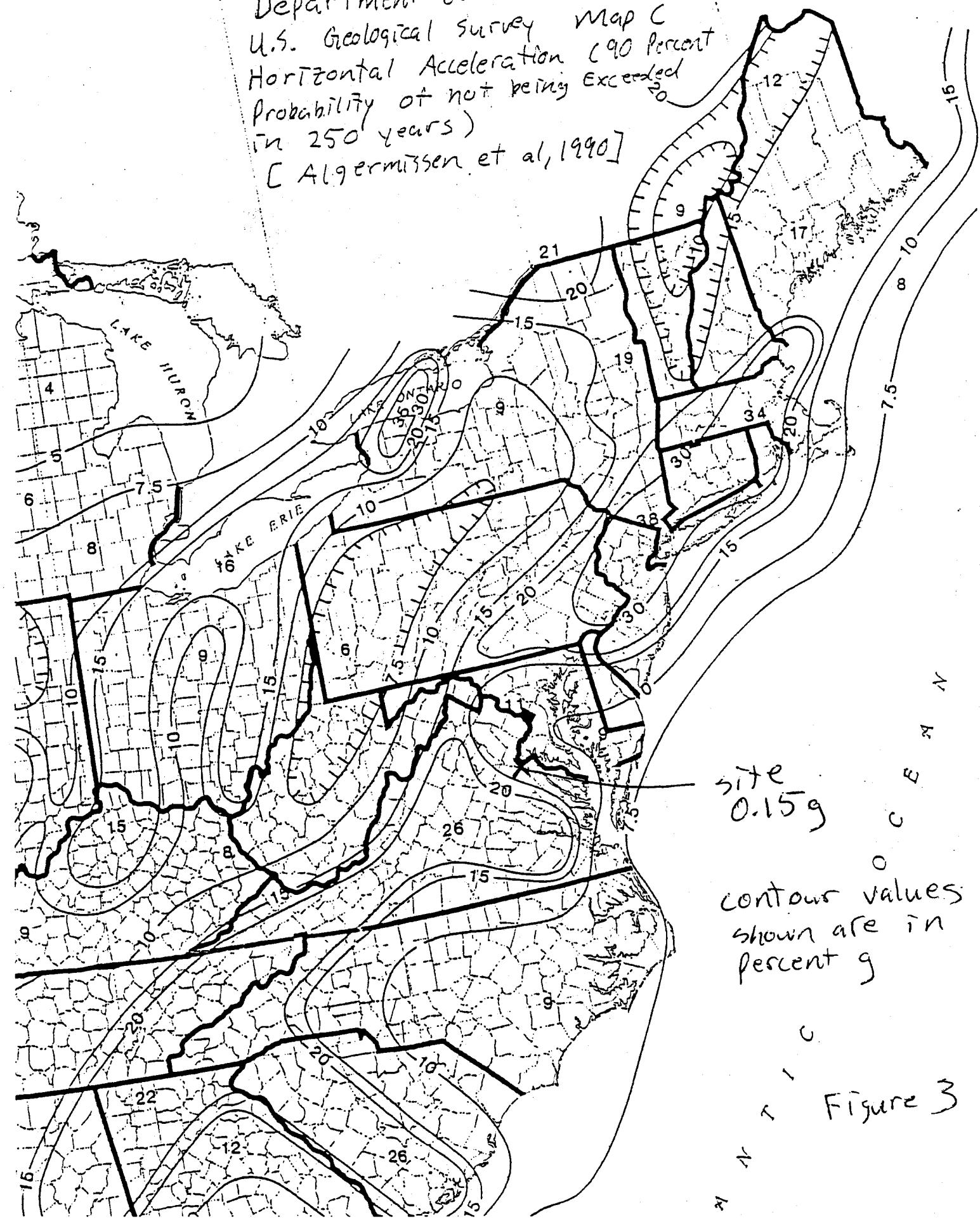


Figure 2

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Department of the Interior,  
U.S. Geological Survey Map C  
Horizontal Acceleration (90 percent  
probability of not being exceeded  
in 250 years)  
[Algernissen et al, 1990]





Written by: Doug Mandeville Date: 2/22/01

Reviewed by: Bill Steier ws Date: 3/21/01

Client: WM

Project: King George XL

Proj./Proposal No.: ME0169

Task No.: 05

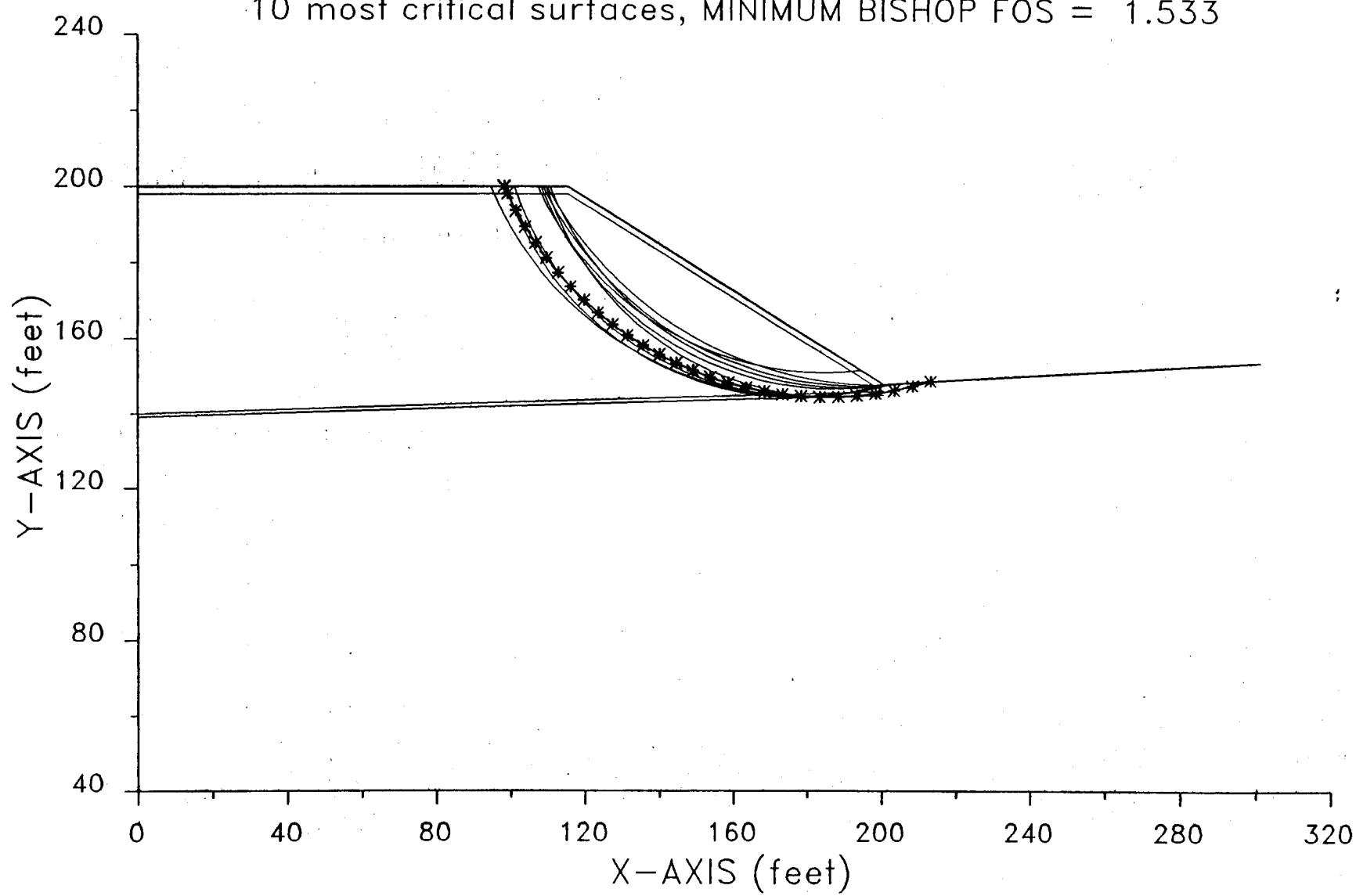
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## ATTACHMENT A

KG2EX 3-15-\*\* 11:08

King George Bioreactor

10 most critical surfaces, MINIMUM BISHOP FOS = 1.533



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* Method of Slices *
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```

Problem Description : King George Bioreactor

**SEGMENT BOUNDARY COORDINATES****3 SURFACE boundary segments**

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	200.0	115.0	200.0	1
2	115.0	200.0	200.0	148.0	1
3	200.0	148.0	300.0	154.0	2

**4 SUBSURFACE boundary segments**

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	198.0	115.0	198.0	3
2	115.0	198.0	200.0	146.0	3
3	.0	140.0	200.0	146.0	4
4	.0	139.0	200.0	145.0	2

**ISOTROPIC Soil Parameters****4 Soil unit(s) specified**

Soil Unit No.	Weight (pcf)	Cohesion Sat. (psf)	Friction Intercept (deg)	Pore Pressure Parameter Ru	Water Constant (psf)	Surface No.
1	125.0	125.0	250.0	25.00	.000	0
2	125.0	125.0	250.0	25.00	.000	0
3	75.0	75.0	.0	33.00	.000	1
4	100.0	100.0	.0	18.00	.000	1

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

**Soil Unit # 3**

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	.0	500.0
2	770.0	500.0
3	25000.0	16235.0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

1000 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 100 points equally spaced along the ground surface between  $x = 175.0$  ft and  $x = 240.0$  ft

Each surface terminates between  $x = 40.0$  ft and  $x = 150.0$  ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is  $y = .0$  ft

\* \* \* \* \* DEFAULT SEGMENT LENGTH SELECTED BY XSTABL \* \* \* \* \*

5.0 ft line segments define each trial failure surface.

**ANGULAR RESTRICTIONS**

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees  
Upper angular limit := -5.0 degrees

\*\*\*\*\*

-- WARNING -- WARNING -- WARNING -- (# 48)  
\*\*\*\*\*  
Negative effective stresses were calculated at the base of a slice. This warning is usually reported for cases where slices have low self weight and a relatively high "c" shear strength parameter. In such cases, this effect can only be eliminated by reducing the "c" value.  
\*\*\*\*\*

USER SELECTED option to maintain strength greater than zero

Factors of safety have been calculated by the :

\* \* \* \* \* SIMPLIFIED BISHOP METHOD \* \* \* \* \*

7.	1.560	186.45	226.11	81.60	212.42	109.17	7.329E+06
8.	1.560	177.96	226.78	81.93	200.61	100.54	8.572E+06
9.	1.563	186.46	231.44	84.74	201.92	107.80	7.207E+06
10.	1.573	178.14	236.07	91.39	203.23	94.20	1.045E+07

\* \* \* END OF FILE \* \* \*

The most critical circular failure surface  
is specified by 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	212.42	148.75
2	207.61	147.41
3	202.73	146.32
4	197.80	145.49
5	192.83	144.92
6	187.84	144.61
7	182.84	144.56
8	177.84	144.78
9	172.87	145.25
10	167.92	145.99
11	163.02	146.98
12	158.18	148.23
13	153.41	149.73
14	148.72	151.47
15	144.14	153.46
16	139.66	155.69
17	135.30	158.15
18	131.09	160.83
19	127.01	163.73
20	123.10	166.84
21	119.35	170.15
22	115.78	173.65
23	112.40	177.33
24	109.21	181.19
25	106.24	185.21
26	103.47	189.37
27	100.93	193.68
28	98.62	198.11
29	97.75	200.00

\*\*\*\* Simplified BISHOP FOS = 1.533 \*\*\*\*

The following is a summary of the TEN most critical surfaces

Problem Description : King George Bioreactor

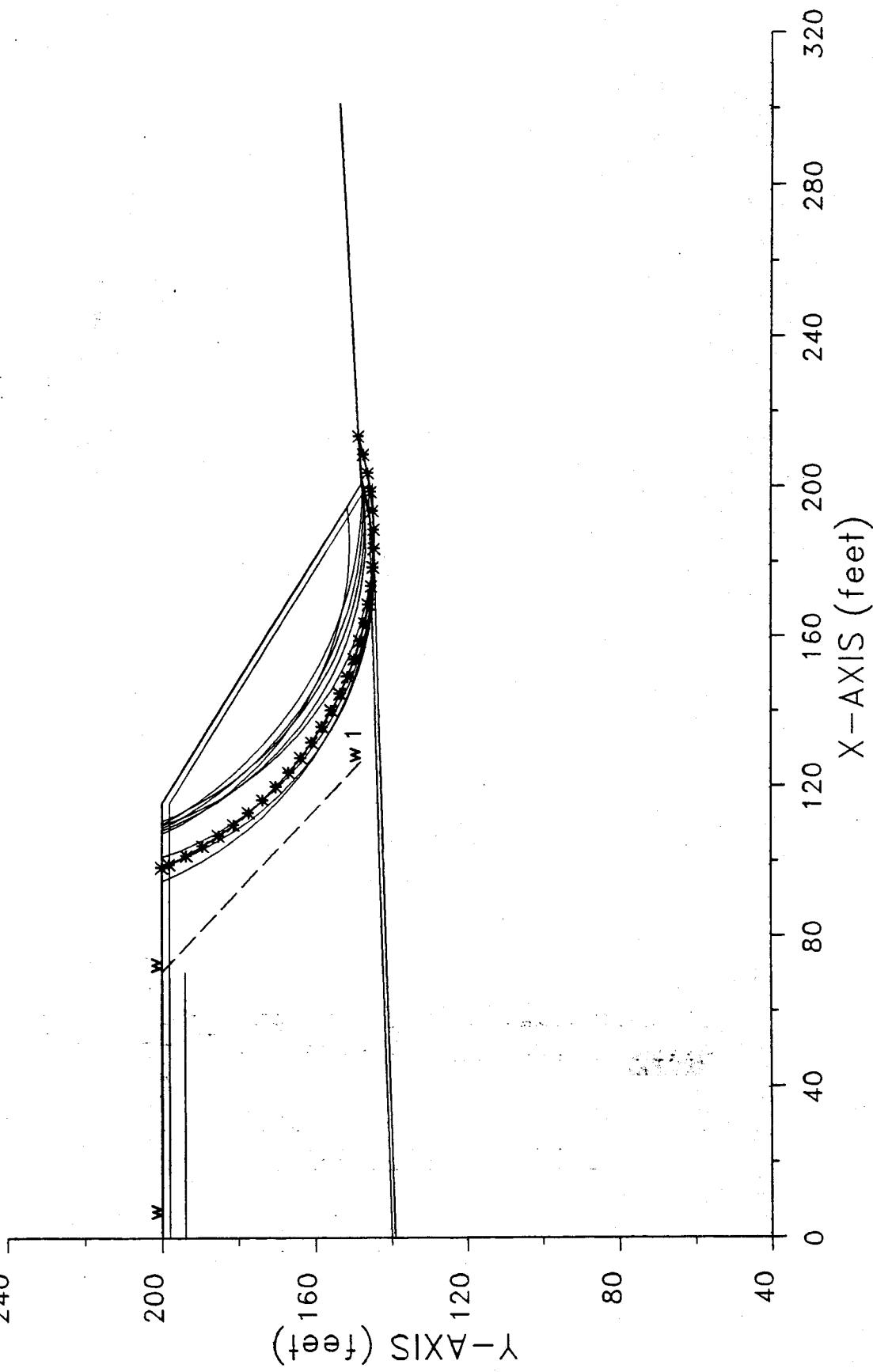
FOS (BISHOP)	Circle Center x-coord (ft)	Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	1.533	184.43	240.07	95.52	212.42	97.75 1.009E+07
2.	1.536	193.18	242.20	94.75	206.52	108.37 7.198E+06
3.	1.546	183.80	235.92	84.89	194.04	106.91 6.103E+06
4.	1.551	189.33	232.58	85.52	203.23	110.25 6.638E+06
5.	1.557	197.77	248.74	100.96	211.11	109.38 7.137E+06
6.	1.558	176.05	226.89	82.40	199.95	98.19 8.986E+06

KG2EX.OPT 3-15-101 11:10a

Page 2 of 2

KG2TR 3-15-\* 11:17

King George Bioreactor  
10 most critical surfaces, MINIMUM BISHOP FOS = 1.533



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```

## Problem Description : King George Bioreactor

## SEGMENT BOUNDARY COORDINATES

## 3 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	200.0	115.0	200.0	1
2	115.0	200.0	200.0	148.0	1
3	200.0	148.0	300.0	154.0	2

## 6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	198.0	115.0	198.0	3
2	115.0	198.0	200.0	146.0	3
3	.0	198.0	70.0	198.0	5
4	.0	194.0	70.0	194.0	5
5	.0	140.0	200.0	146.0	4
6	.0	139.0	200.0	145.0	2

## ISOTROPIC Soil Parameters

## 5 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Water Constant (psf)	Water Surface No.
1	125.0	125.0	250.0	25.00	.000	.0	0
2	125.0	125.0	250.0	25.00	.000	.0	0
3	75.0	75.0	.0	33.00	.000	.0	1
4	100.0	100.0	.0	18.00	.000	.0	1
5	120.0	120.0	.0	30.00	.000	.0	1

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

## Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	.0	500.0
2	770.0	500.0
3	25000.0	16235.0

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 3 coordinate points

```
*****
* PHREATIC SURFACE,
*****
*****
```

Point No.	x-water (ft)	y-water (ft)
1	5.00	200.00
2	70.00	200.00
3	126.00	148.00

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

1000 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 100 points equally spaced along the ground surface between x = 175.0 ft and x = 240.0 ft

Each surface terminates between x = 40.0 ft and x = 150.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

\* \* \* \* \* DEFAULT SEGMENT LENGTH SELECTED BY XSTABL \* \* \* \* \*

5.0 ft line segments define each trial failure surface.

## ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees  
Upper angular limit := -5.0 degrees

\*\*\*\*\*  
-- WARNING -- WARNING -- WARNING -- (# 48)  
\*\*\*\*\*  
Negative effective stresses were calculated at the base of a slice.  
This warning is usually reported for cases where slices have low self weight and a relatively high "c" shear strength parameter. In such cases, this effect can only be eliminated by reducing the "c" value.  
\*\*\*\*\*

-----  
USER SELECTED option to maintain strength greater than zero  
-----

Factors of safety have been calculated by the :

\* \* \* \* \* SIMPLIFIED BISHOP METHOD \* \* \* \* \*

The most critical circular failure surface is specified by 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	212.42	148.75
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3	202.73	146.32
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20	123.10	166.84
21	119.35	170.15
22	115.78	173.65
23	112.40	177.33
24	109.21	181.19
25	106.24	185.21
26	103.47	189.37
27	100.93	193.68
28	98.62	198.11

29 97.75 200.00

\*\*\*\* Simplified BISHOP FOS = 1.533 \*\*\*\*

The following is a summary of the TEN most critical surfaces

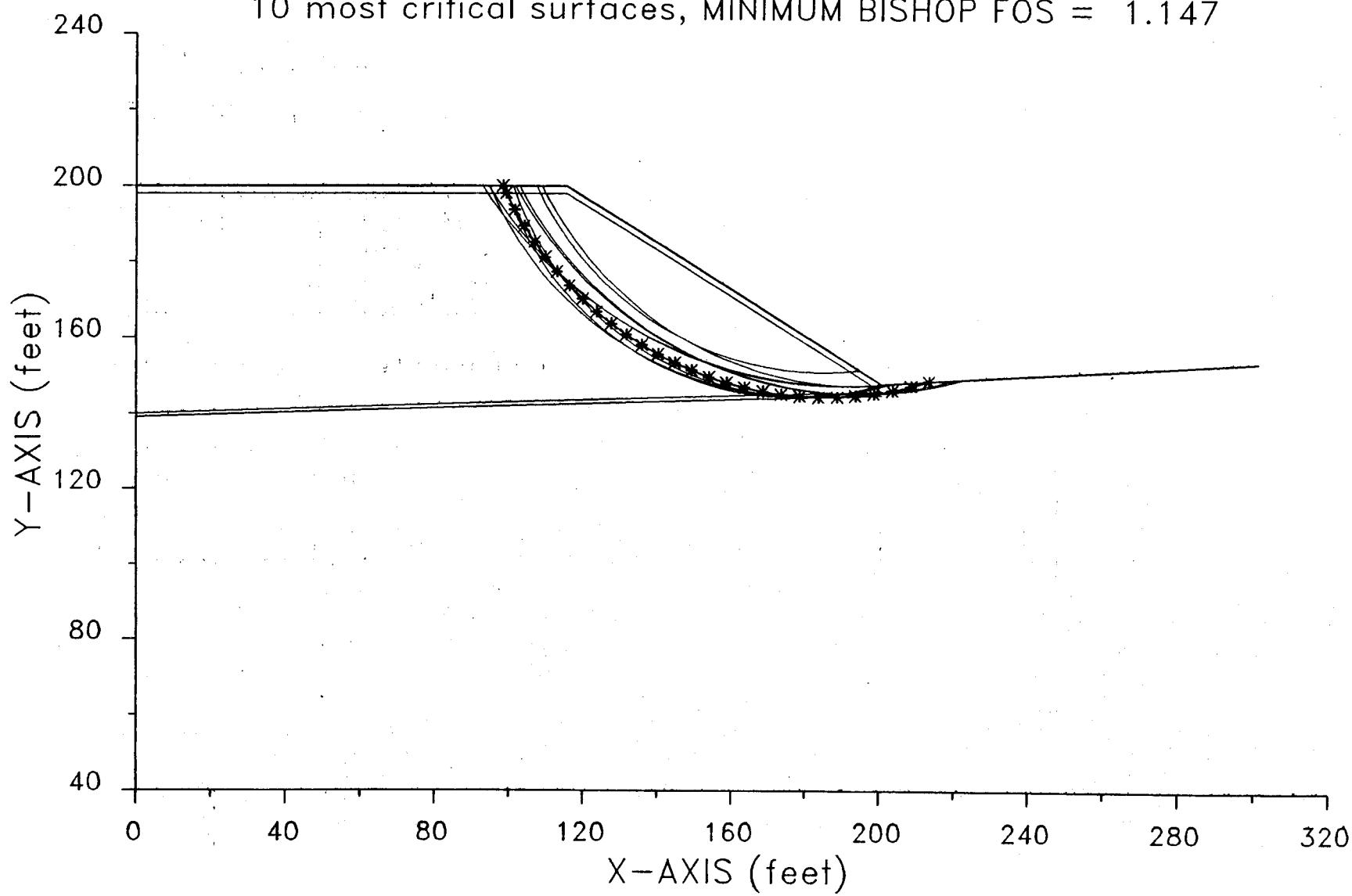
Problem Description : King George Bioreactor

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
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6.	1.558	176.05	226.89	82.40	199.95	98.19	8.986E+06
7.	1.560	186.45	226.11	81.60	212.42	109.17	7.329E+06
8.	1.560	177.96	226.78	81.93	200.61	100.54	8.572E+06
9.	1.563	186.46	231.44	84.74	201.92	107.80	7.207E+06
10.	1.573	178.14	236.07	91.39	203.23	94.20	1.045E+07

{ \* \* \* END OF FILE \* \* \*

King George Bioreactor

10 most critical surfaces, MINIMUM BISHOP FOS = 1.147



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* Method of Slices *
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*****
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Problem Description : King George Bioreactor

**SEGMENT BOUNDARY COORDINATES****3 SURFACE boundary segments**

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	200.0	115.0	200.0	1
2	115.0	200.0	200.0	148.0	1
3	200.0	148.0	300.0	154.0	2

**4 SUBSURFACE boundary segments**

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	198.0	115.0	198.0	3
2	115.0	198.0	200.0	146.0	3
3	.0	140.0	200.0	146.0	4
4	.0	139.0	200.0	145.0	2

**ISOTROPIC Soil Parameters****4 Soil unit(s) specified**

Soil Unit No.	Weight (pcf)	Moist Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Water Constant (psf)	Surface No.
1	125.0	125.0	250.0	25.00	.000	.0	0
2	125.0	125.0	250.0	25.00	.000	.0	0
3	75.0	75.0	.0	33.00	.000	.0	1
4	100.0	100.0	.0	18.00	.000	.0	1

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

**Soil Unit # 3**

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	.0	500.0
2	770.0	500.0
3	25000.0	16235.0

A horizontal earthquake loading coefficient of .150 has been assigned

A vertical earthquake loading coefficient of .000 has been assigned

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

1000 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 100 points equally spaced along the ground surface between x = 175.0 ft and x = 240.0 ft

Each surface terminates between x = 40.0 ft and x = 150.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

\*\*\*\*\* DEFAULT SEGMENT LENGTH SELECTED BY XSTABL \*\*\*\*\*

5.0 ft line segments define each trial failure surface.

**ANGULAR RESTRICTIONS**

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees  
Upper angular limit := -5.0 degrees

\*\*\*\*\*  
-- WARNING -- WARNING -- WARNING -- WARNING -- (# 48)  
\*\*\*\*\*  
Negative effective stresses were calculated at the base of a slice.

This warning is usually reported for cases where slices have low self weight and a relatively high "c" shear strength parameter. In such cases, this effect can only be eliminated by reducing the "c" value.  
\*\*\*\*\*

-----  
USER SELECTED option to maintain strength greater than zero  
-----

Factors of safety have been calculated by the :

\* \* \* \* \* SIMPLIFIED BISHOP METHOD \* \* \* \* \*

The most critical circular failure surface  
is specified by 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	212.42	148.75
2	207.61	147.41
3	202.73	146.32
4	197.80	145.49
5	192.83	144.92
6	187.84	144.61
7	182.84	144.56
8	177.84	144.78
9	172.87	145.25
10	167.92	145.99
11	163.02	146.98
12	158.18	148.23
13	153.41	149.73
14	148.72	151.47
15	144.14	153.46
16	139.66	155.69
17	135.30	158.15
18	131.09	160.83
19	127.01	163.73
20	123.10	166.84
21	119.35	170.15
22	115.78	173.65
23	112.40	177.33
24	109.21	181.19
25	106.24	185.21
26	103.47	189.37
27	100.93	193.68
28	98.62	198.11
29	97.75	200.00

\*\*\*\* Simplified BISHOP FOS = 1.147 \*\*\*\*

The following is a summary of the TEN most critical surfaces

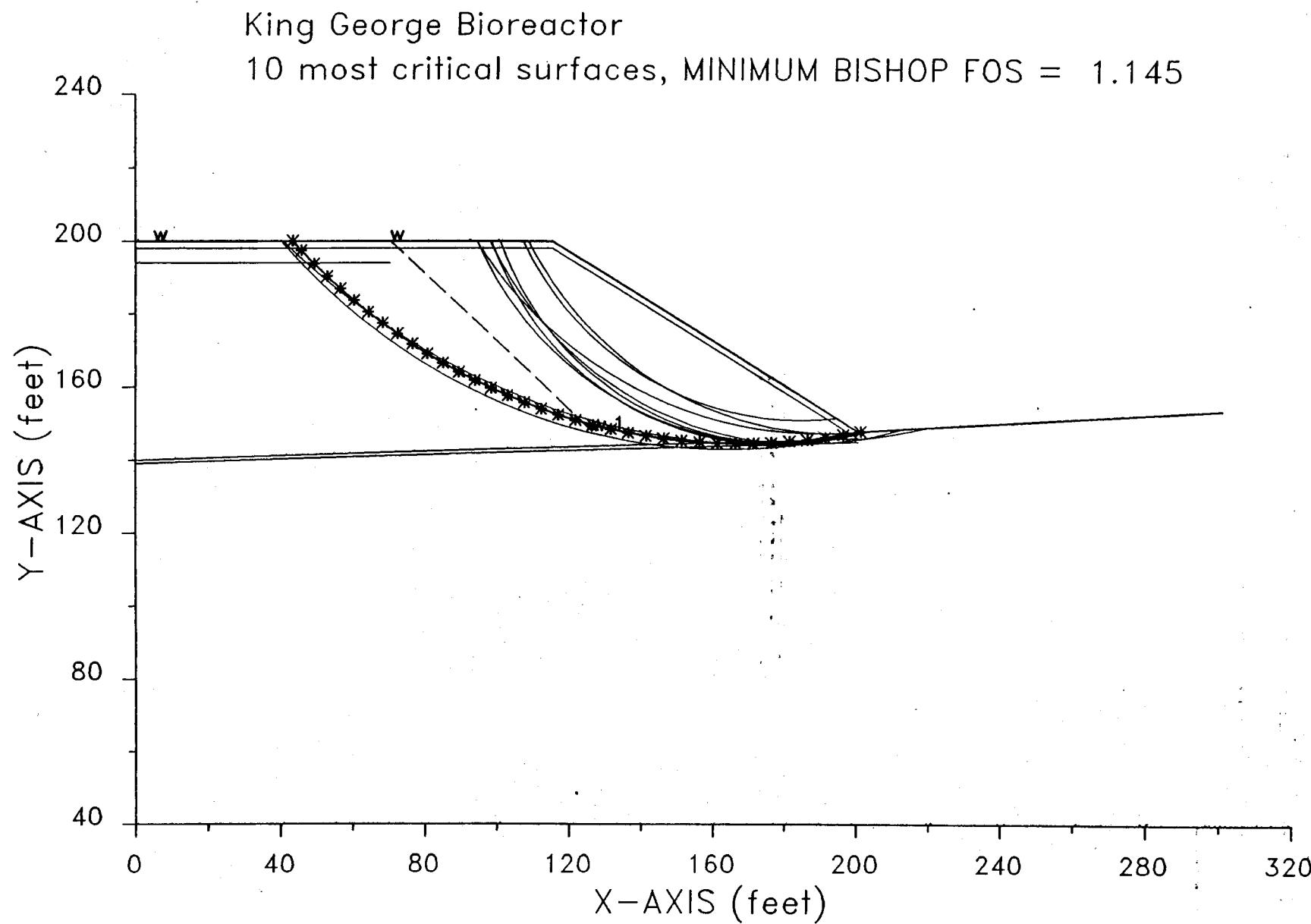
Problem Description : King George Bioreactor

FOS (BISHOP)	Circle Center x-coord	Radius y-coord	Initial x-coord	Terminal x-coord	Resisting Moment
KG2EXEQ.OPT	3-20-101	11:18a			

		(ft)	(ft)	(ft)	(ft)	(ft)	(ft-lb)
1.	1.147	184.43	240.07	95.52	212.42	97.75	9.610E+06
2.	1.171	176.05	226.89	82.40	199.95	98.19	8.560E+06
3.	1.173	178.14	236.07	91.39	203.23	94.20	9.950E+06
4.	1.179	177.96	226.78	81.93	200.61	100.54	8.179E+06
5.	1.180	193.18	242.20	94.75	206.52	108.37	6.918E+06
6.	1.183	188.93	259.44	112.04	201.26	93.97	1.080E+07
7.	1.183	183.80	235.92	84.89	194.04	106.91	5.856E+06
8.	1.187	192.66	247.89	102.34	219.65	102.25	9.207E+06
9.	1.190	193.33	250.45	105.17	222.27	101.09	9.734E+06
10.	1.190	190.65	265.91	118.42	203.89	92.29	1.157E+07

\* \* \* END OF FILE \* \* \*

KG2TREQ 3-15-\*\* 11:17



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```

Problem Description : King George Bioreactor

**SEGMENT BOUNDARY COORDINATES****3 SURFACE boundary segments**

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	200.0	115.0	200.0	1
2	115.0	200.0	200.0	148.0	1
3	200.0	148.0	300.0	154.0	2

**6 SUBSURFACE boundary segments**

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	198.0	115.0	198.0	3
2	115.0	198.0	200.0	146.0	3
3	.0	198.0	70.0	198.0	5
4	.0	194.0	70.0	194.0	5
5	.0	140.0	200.0	146.0	4
6	.0	139.0	200.0	145.0	2

**ISOTROPIC Soil Parameters****5 Soil unit(s) specified**

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	250.0	25.00	.000	.0	0
2	125.0	125.0	250.0	25.00	.000	.0	0
3	75.0	75.0	.0	33.00	.000	.0	1
4	100.0	100.0	.0	18.00	.000	.0	1
5	120.0	120.0	.0	30.00	.000	.0	1

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

**Soil Unit # 3**

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	.0	500.0
2	770.0	500.0
3	25000.0	16235.0

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 3 coordinate points

```
*****
* PHREATIC SURFACE,
*****
*****
```

Point No.	x-water (ft)	y-water (ft)
1	5.00	200.00
2	70.00	200.00
3	126.00	148.00

A horizontal earthquake loading coefficient of .150 has been assigned

A vertical earthquake loading coefficient of .000 has been assigned

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

1000 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 100 points equally spaced along the ground surface between x = 175.0 ft and x = 240.0 ft

Each surface terminates between x = 40.0 ft and x = 150.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

\*\*\*\*\* DEFAULT SEGMENT LENGTH SELECTED BY XSTABL \*\*\*\*\*

5.0 ft line segments define each trial failure surface.

**ANGULAR RESTRICTIONS**

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees

Upper angular limit := -5.0 degrees

\*\*\*\*\* WARNING -- WARNING -- WARNING -- WARNING -- (# 48) \*\*\*\*\*

Negative effective stresses were calculated at the base of a slice. This warning is usually reported for cases where slices have low self weight and a relatively high "c" shear strength parameter. In such cases, this effect can only be eliminated by reducing the "c" value.

**USER SELECTED option to maintain strength greater than zero**

Factors of safety have been calculated by the :

\*\*\*\*\* SIMPLIFIED BISHOP METHOD \*\*\*\*\*

The most critical circular failure surface is specified by 36 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	200.61	148.04
2	195.69	147.10
3	190.76	146.31
4	185.80	145.67
5	180.82	145.18
6	175.83	144.84
7	170.84	144.65
8	165.84	144.61
9	160.84	144.73
10	155.85	144.99
11	150.86	145.40
12	145.89	145.96
13	140.95	146.68
14	136.02	147.54
15	131.12	148.54
16	126.26	149.70
17	121.43	151.00
18	116.64	152.45
19	111.90	154.04
20	107.21	155.77

21	102.58	157.64
22	98.00	159.65
23	93.48	161.80
24	89.03	164.08
25	84.66	166.49
26	80.35	169.04
27	76.13	171.72
28	71.99	174.52
29	67.93	177.44
30	63.96	180.48
31	60.09	183.65
32	56.32	186.93
33	52.64	190.32
34	49.07	193.81
35	45.61	197.42
36	43.27	200.00

\*\*\*\* Simplified BISHOP FOS = 1.145 \*\*\*\*

The following is a summary of the TEN most critical surfaces

Problem Description : King George Bioreactor

FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	1.145	167.05	310.66	166.05	200.61	43.27 2.850E+07
2.	1.147	184.43	240.07	95.52	212.42	97.75 9.610E+06
3.	1.168	163.19	304.20	161.19	203.89	40.22 3.036E+07
4.	1.171	176.05	226.89	82.40	199.95	98.19 8.560E+06
5.	1.173	178.14	236.07	91.39	203.23	94.20 9.950E+06
6.	1.175	176.22	336.83	192.61	219.65	40.66 3.467E+07
7.	1.179	177.96	226.78	81.93	200.61	100.54 8.179E+06
8.	1.180	193.18	242.20	94.75	206.52	108.37 6.918E+06
9.	1.183	188.93	259.44	112.04	201.26	93.97 1.080E+07
10.	1.183	183.80	235.92	84.89	194.04	106.91 5.856E+06

\*\*\* END OF FILE \*\*\*

